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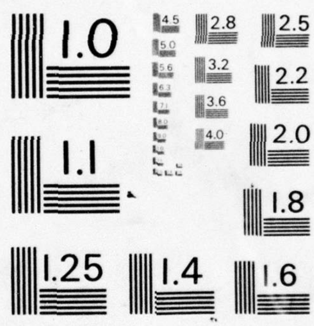

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Monterey, California

THESIS

THE SYSTEMS APPROACH TO MANAGEMENT:
A PARADIGM FOR THE
TEST AND EVALUATION PROCESS

by

William Michael Branch

September, 1976

Advisors	J. W. Creighton
	Thad Perry

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THE SYSTEMS APPROACH TO MANAGEMENT:
A PARADIGM FOR THE
TEST AND EVALUATION PROCESS

by

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ABSTRACT

This thesis addresses the Test and Evaluation process and demonstrates, through application of a dynamic systems model, that the Test and Evaluation process is a conglomerate of lower-order systems. Each system can be characteristically analyzed by focusing on objectives, inputs/outputs, interfaces, environmental, and effectiveness dimensions. Hence the systems approach to management is suggested as a paradigm for the Test and Evaluation process. This approach provides a systematic way of thinking about the job of management and emphasizes viewing the Test and Evaluation system as a whole instead of as segregated parts. The classic functions of management can be put in juxtaposition with the phases of Test and Evaluation to provide a better insight to management of scarce resourses. Implementation of a strategy is perhaps the most important first step in practically using the systems approach and as such stimulates the manager to think in the proper perspective.

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

AIRTEVRON	Air Test and Evaluation Squadron
BIS	Board of Inspection and Survey
CNM	Chief of Naval Material
CNO	Chief of Naval Operations
DA	Developing Agency
DSARC	Defense System Acquisition Review Council
DT&E	Developmental Test and Evaluation
FOT&E	Follow-on Operational Test and Evaluation
IOT&E	Initial Operational Test and Evaluation
JET	Joint Evaluation Team
NAVAIRSYSCOM	Naval Air Systems Command
NAVAIRTESTCEN	Naval Air Test Center
NPG	Naval Postgraduate School
OPEVAL	Operational Evaluation
OPTEVFOR	Operational Test and Evaluation Force
OT&E	Operational Test and Evaluation
PACMISTESTCEN	Pacific Missile Test Center
PAT&E	Production Acceptance Test and Evaluation
RDT&E	Research, Development, Test and Evaluation
SecDef	Secretary of Defense
SecNav	Secretary of the Navy
T&E	Test and Evaluation
TECHEVAL	Technical Evaluation
TEMP	Test and Evaluation Master Plan

ACKNOWLEDGEMENT

I wish to thank the many people who generously devoted their time to provide me with the information from which this thesis was developed. I particularily wish to thank Wally Creighton and Thad Perry for their constructive advice and guidance as advisors. Comments are not identified with any particular interviewee in this thesis and should only be taken as the author's interpretation of the interview. As such the thoughts and ideas expressed are not necessarily the opinion of any particular agency.

I. INTRODUCTION

A. BACKGROUND

Since the mid 1960's all phases of the weapon systems acquisition process within the Department of Defense (DoD) have undergone criticism and change. Excessive life cycle cost growth and poor operational performance of weapon systems upon entering use have been frequent problems. As a result, several committees were formed to extensively study these problems; among them the President's Blue Ribbon Defense Panel, a General Accounting Office committee, and the Congress's Commission on Government Procurement. All have consistently identified Test and Evaluation as a major problem area.

The acquisition policy for major weapon systems has evolved from the high risk "total package procurement" philosophy of development under a fixed-price contract to the more conservative "fly-before-buy" concept of developing a new system under hybrid cost-type contracts. Under the latter concept program risks and progress are assessed at specific milestone events prior to proceeding into production. Concurrency between development and production is being minimized and greater emphasis is placed on early determination of operational suitability prior to production commitments. This change in system acquisition policy has thus placed greater emphasis on the Test and Evaluation process.

The overall Navy Test and Evaluation (T&E) process can be viewed as a system composed of testing agencies interacting in such a manner as to test and evaluate a weapon system. This process is composed basically of three types of T&E; Development Test and Evaluation (DT&E), Operational Test and Evaluation (OT&E), and Production Acceptance Test and Evaluation (PAT&E). Each type consists of a heirarchy of several layers of organizational systems; from Secretary of the Navy (SecNav) down to the individual field activities under the Naval Air Systems Command (NAVAIRSYSCOM), or to the squadrons under the Operations Test and Evaluation Force (OPTEVFOR). Each of the field activities can in turn be subdivided into various systems; from the Directorate level down to the Section level. Each of these layers of systems within the types of T&E performed can be thought of as parts or elements within the total T&E process.

The T&E process within DoD is characteristically bureaucratic. Chief of Naval Operations (CNO) Instruction 3960.10, DoD Directive 5000.3 and SecNav Instruction 5000.1, among others, have established the WHO, WHAT, WHY, and WHEN of the Navy T&E process. However the question of HOW to effectively manage T&E remains outstanding and must be addressed. If history is any indication of the future the T&E process will become steadily more complex as the environment about the weapons acquisition process becomes more dynamic, as scarce resourses become more scarce, and as weapon systems become more complex. The question of HOW to manage the T&E process of the future becomes a perplexing and important issue. The manager of the

future must be able to cope with the ever changing dynamic nature of the environment about him and also with the complexities of the many organizational systems which comprise the total T&E system process. This thesis suggests a managerial approach which could cope with these complexities. This approach, the systems approach to management, can provide a framework for thinking which guides the manager of any organizational system to consider the objectives, environment, inputs and outputs, and interfaces that affect that system; and more importantly, to view the T&E system as a whole instead of as fragmented parts.

B. OBJECTIVES OF THESIS

The primary objectives of this thesis are two fold. First is to show that the Test and Evaluation process is in fact a system composed of many interrelated organizational systems. The second objective is to show that the systems approach to management offers a framework for managing the Test and Evaluation process of the future and as such becomes a useful managerial tool.

C. SCOPE OF THESIS

The systems approach to management can apply to any system or subsystem within the total Test and Evaluation process. This thesis is however restricted in scope to the Navy Test and Evaluation process within the Department of Defense. This thesis will draw from managerial experience gained during the Test and Evaluation process of weapon systems, i.e. F-14 et al

and relate the future managerial complexities of T&E to the systems approach of management. The overall concepts are ceraintly applicable however to T&E in general.

D. METHODOLOGY

This study is comprised of five basic phases, the last four of which overlap to some extent, but are nevertheless distinctly different.

Phase I.	Identification of the problem and establishment of basic objectives.
Phase II.	Literature search in the areas of Systems Management, Program Management, Test and Evaluation, Government manuals, specifications and directives.
Phase III.	Information gathering from various agencies. Appendix A presents organizations interviewed for information pertaining to this thesis.
Phase IV.	Analysis of information.
Phase V.	Preparation of thesis.

The process of analyzing Test and Evaluation begins by first analyzing the systems approach to management. Chapter II presents the concepts and characteristics of the systems approach and formulates a working systems model which can be applied throughout this thesis.

Chapter III analyzes the Test and Evaluation process and policies and delineates the basic types of test and evaluation performed on a weapon system. Chapter IV analyzes the separate types of T&E from a systems view applying the systems model presented in Chapter II. Chapter V analyzes the total T&E

process from a systems view. Chapter VI concludes the text by relating the systems approach to the management functions within the T&E process and suggests the importance of strategy formulation and implementation. Conclusions then summarize the basic findings of this thesis.

II. THE SYSTEMS APPROACH TO MANAGEMENT

The systems approach to management provides a systematic framework of thinking about the job of management and stresses the interrelatedness and interdependency of the parts to the whole. A systems approach has long been observed by scholars and practitioners alike. One of the earliest recorded statements concerning systems and systems management can be traced to 500 B.C. when Mencius stated:

> "Whoever pursues a business in this world must have a system. A business which has attained success without a system does not exist. From ministers and generals down to the hundreds of craftsmen, everyone of them, both skilled and unskilled, use this system. The skilled may at times accomplish a circle and a square by their own dexterity. But with a system, even the unskilled may achieve the same results, though dexterity they have none. Hence, every craftsman possesses a system as a model. Now, if we govern the empire, or a large state, without a system as a model, are we not even less intelligent than a common craftsman?" [George, 1970]

However, only since the mid 1960's has the systems approach evolved into the managerial area. Appendix B presents the evolution of management concepts and places the systems approach of management in perspective with other classical theories.

A. THE CONCEPT OF A SYSTEM

A starting point in the analysis of the systems approach is first to define what a system is. Noted authors in the field have defined systems as the following:

> "A system is an array of components designed to accomplish a particular objective according to plan." [Johnson, 1973]

> "A system is an organized, unitary whole composed of two or more interdependent parts, components, or subsystems and delineated by identifiable boundaries from its environmental suprasystem." [Kast, 1974]

> "A system is an organized or complex whole; an assemblage or combination of things or parts forming a complex or unitary whole." [Cleland, 1975]

There are about as many definitions of systems as there are authors in the area, but all have certain common characteristics. The following definition will serve as a composite definition of the term "system":

> "A system is a group of elements, either physical or non-physical in nature, that exhibit a set of interrelations among themselves and interact together toward one or more goals, objectives, or ends." [Alexander, 1974]

Diagnosis of the above definition of "system" will be useful and will enable correlation with the management function within the Test and Evaluation process.

The word "elements" may refer to physical objects such as component parts of an airplane, or it may also refer to interrelated activities such as the managerial functions of planning, organizing, directing, and controlling. An "element" of a system may also be a lower-order system, hence a subsystem of a larger system such as T&E activities within the T&E system. Relations that exist among system elements may be examined in terms of type of relation present, whether spatial, time, cause and effect, physical, logical, and/or mathematical.

The purpose of a system is shown by its stated goals or objectives, the reason why the system was created. When a system is actually a subsystem, or a clearly defined integral

part of a larger system, its purpose is usually to support the major system activity.

An important concept in systems theory is that of system boundaries. Boundaries differentiate between intra- and inter-systemic relations and only when these boundaries have been clearly defined can focus be directed toward system elements and interrelations.

The system of concern in this thesis is the Test and Evaluation system; however some mention of the managerial systems within the T&E system will be made. A dynamic model will be used to analyze the system and its various characteristics. The dynamic model is one of the many types of models which can be used to represent a system; other models are summarized in Appendix C.

B. THE DYNAMIC SYSTEMS MODEL

Dynamic systems are systems in which certain elements are altered in form through an ongoing, self-controlling process to create other unique distinct elements [Alexander, 1974]. These systems are isomorphic in character and exhibit a purposeful activity in the achievement of their goals and objectives. In general, dynamic systems display the general attributes associated with living things; purposeful activity, self-regulation, self-direction, and predictable behavior. Inputs are transformed into outputs in a given environment. A schematic model of the dynamic system as used **for** this thesis is presented in Figure 1. The significant features of the dynamic system, as they relate to T&E, are summarized below.

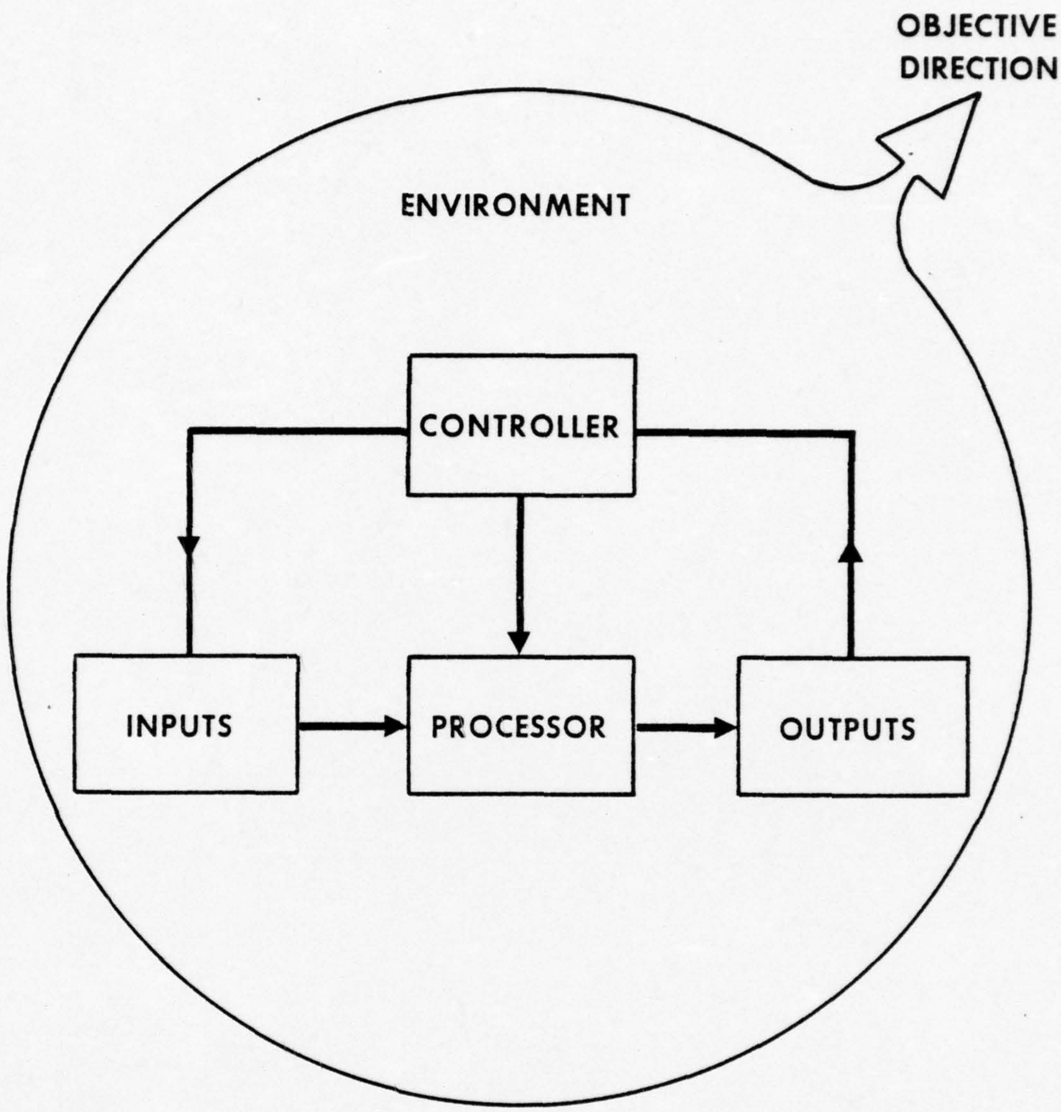


FIGURE 1

DYNAMIC SYSTEMS MODEL

1. System Objectives

Objectives of a system are needed before the system can exist, for they describe the purpose and reason for existance of the system, i.e. the direction the system is to take. These objectives usually exist in the form of general and specific objectives. A general objective may be "to perform test and evaluation of the total aircraft". Specific objectives are much more detailed and usually in an exhaustive list. They could include objectives such as "conduct test and evaluation of aircraft flying qualities, performance, weapons/store separation . . .".

2. System Inputs and Outputs

An underlying characteristic of inputs/outputs is that they may be either homogenous or heterogenous in nature. Inputs for a dynamic system are defined as one or more elements in a given dynamic system that are consumed or transformed during the operation of a dynamic process. Outputs are defined as one or more elements in a given dynamic system that are created by the operation of a dynamic system. Wide disparity in input resourses may exist for the T&E system, such as test airplanes, funds, and personnel which are used to generate the various outputs of reports and experience.

Dynamic systems usually require a stream of inputs which may be either continuous or discrete over a period of time in order to function properly. Thus the input/output function can be considered as a flow of matter and/or energy over a period of time.

The relation between the inputs and outputs is of importance in describing the dynamic system. This in essence means knowing the type and quantity of inputs which are necessary to produce the required outputs. This relation also leads to determination of the system efficiency as will be mentioned in a later section.

3. System Processor

The processor is the site or environment where the interaction among system elements takes place. It is the place where transformation of the inputs to outputs occur. The processor may have physical dimensions ranging from a very small confined area to a large ill-defined region. It could also be conceptual in nature, existing only in the minds of men. Processors may be machines, equipments, biological units, the human mind, T&E activities, Directorates, or Sections. For a T&E activity the processor is composed of elements of Directorates, which are systems themselves. They are composed of elements of Branches which are composed of elements of Sections which are composed of elements of personnel. Each of the systems and subsystems are a part of the total T&E system process.

4. System Controller

The controller is that element in the dynamic system that controls the flow of inputs to the processor and establishes the mode of operation for the processor. The controller determines the way the system will meet its objectives. He can do this by providing guidelines and/or rules by which the

system must operate to achieve predictable output of satisfactory quality and quantity. Thus the ultimate performance of the dynamic system depends to a great extent on the controller's design and operation.

The controller has two separate yet interrelated types of activity. He first regulates the flow of inputs in accordance with predetermined input/output relations to maintain a stable, dynamically balanced system. This could include such actions as staffing the T&E activity to appropriate levels with the proper technically competent people. Secondly the controller establishes the processor's overall operating characteristics by structuring the procedures and activities to be used in the transformation process. This could include setting certain quality and quantity standards for work performance.

5. System Control Loop

The control loop encompasses the entire process from input flow to output flow through control by the controller. Needless to say, the control of a dynamic system depends on the functional quality of the entire control loop. All elements of the system must function properly.

The quality of the control loop performance depends on the information derived from systemic outputs. For system effectiveness those attributes of the output stream that are most important in determining the degree of achievement of system objectives or those that define the system operating characteristics are the ones that must be measured.

The type of control loop involved in T&E systems is the "open-loop system" as opposed to the "closed-loop system". The terms "open" and "closed" denote the degree of interaction between a given system and its environment. Open-loop systems are those in which human beings act as the controller. This type of system lacks a substantial degree of self-regulating capacity and its overall stability is significantly diminished. Thus the managerial capability of the controller, i.e. the manager, plays an important function in maintaining system stability and effectiveness.

6. System Feedback

The term "feedback" can imply two separate meanings. First, feedback may refer to the data gathering process, as in gathering information for the decision making process. The term may also denote the direct modification of the input stream by the output stream of the system without direct controller intervention. The first reference to feedback involves the control loop of the dynamic system. Here the controller initiates or has control over the feedback process; such as questions he may ask or reports he may request. Where the controller has no control, as in the latter form of feedback, the process is more mechanical such as the thermostat. The T&E systems should consist of the first type of feedback discussed, that of information gathering by the controller.

7. System Environment

The system environment is composed of those factors that influence the operation of the system, and can be

characterized as either stable, dynamic, or turbulent in nature. The system cannot afford to ignore the environment if it is to survive.

In the Test and Evaluation world the environment is rarely stable, things and/or situations always seem to change. Ocassionally the environment is turbulent, as is the case when a test airplane is lost. However for the majority of the time the environment is dynamic, ever changing, perhaps even in a predictable manner.

It is incumbent upon the managerial system to recognize that external factors to the system do in fact affect the mode of operation of the system. Among the most often encountered factors are funding changes, additional work load requirements, and policy changes by top management.

8. System Interface

System interfaces occur in a compound system environment. Compound systems are those which are composed of two or more distinct subsystems that operate together through the action of a unified controller or manager. Here the processor is subdivided into two or more separate units that must function together to achieve the objectives of the total dynamic system. This is most evident in any organization system such as a Directorate which is composed of Branch subsystems, all under the control of a Director.

An underlying characteristic of compound systems is the interface required with other systems. Direct interface is the point where the output of one system becomes the input

of another system. The information interface is another type of interface which may exist. In this case the linkage between the two systems is informational rather than physical.

Compound systems may be either series or parallel in nature. If the output of one system becomes the input to another system, the systems are in series. Such is the case of NAVAIRSYSCOM and the field activities. The outputs of NAVAIRSYSCOM, the task assignments and funding, become the inputs of the field activities.

If two or more dynamic systems are operating independent of each other and their outputs are combined to furnish the inputs to another system, the systems are in parallel. This is the case of a matrix organization where the outputs of various functional sections are combined to furnish the inputs to a Program Manager.

9. <u>System Efficiency and Effectiveness</u>

System efficiency may be simply expressed as performing effectively at minimum expense of resourses. At the Section level this entails such things as using different resourse saving flight test techniques or data reduction procedures. Needless to say, cost reduction and/or cost minimization is always of concern in any system.

System effectiveness is another important parameter. As previously stated, every system has a purpose or objective. The measure of system effectiveness is directly related to the degree to which these objectives of the system are met. Unfortunately in the T&E world this sometimes is a nebulous area,

particularily where more than one objective is involved. Such is the case when the objectives of a T&E system may not be in alignment with the objectives of the contractors or of OPTEVFOR during the T&E process of a weapon system.

Two additional concepts must be considered under systems effectiveness. An evaluation criteria must be firmly established before any evaluation of the systems effectiveness can be made. Whose objectives are important and in what order? The second concept to consider is one of "to satisfice". This term may be defined as the satisfaction or fulfillment of needs or objectives only up to the point where there is insufficient motivation to expend further resourses to achieve greater satisfaction.

Thus the concepts of system efficiency and effectiveness are separate and distinct. Together, however, these two measures provide a means for evaluation of the total systems performance.

C. SYSTEMS CONCEPTS AND MANAGEMENT

The previous sections have presented the concept of a system and the functional characteristics of the dynamic systems model. This section will now relate the systems approach to the management functions.

1. Management Defined

Perhaps everyone has his own definition or conception of what management is. Usually it is stated in terms of functions that managers do, not what management is. In the

context of this thesis management will be defined as "the process whereby unrelated resourses are integrated into a total system for objective accomplishment" [Johnson, 1964]. Performing the function of management is of course done by managers.

Managers attempt to weld human, technological, and capital resourses into an effective, cohesive whole to achieve the objectives of the organization. A manager gets things done by working with people and physical resourses in order to accomplish the objectives of the system. He coordinates and integrates the activities and work of others rather than performing operations himself.

2. Management and the Systems Approach

The effective and efficient function of a system is under the auspices of the controller or the manager of the system. To effectively perform the function of management within the system the manager must be aware of what his system is and the role he and it play in the overall "big picture".

A good manager relies on ideas, resourses, things, tools, and people to achieve objectives. He utilizes such managerial functions as planning, organizing, staffing, directing, and controlling as prescribed by such authors as Koontz and O'Donnell [1968]. In the systems approach to management the managerial functions are not performed as separate entities, rather they are performed in conjunction with operations of the system as a cohesive whole. Any and all operations and functions performed by managers must be oriented toward the objectives of the organization.

In effect the systems approach to management provides the manager with a framework for thinking about the job of management. This approach forces recognition of system objectives, inputs and outputs, the environment, interfaces with other systems, and overall effectiveness. More importantly however it guides the manager to view not only his immediate system but the "whole" system. Management and the systems approach as related to T&E is addressed in more detail in Chapter VI.

D. SYSTEMS SUMMARY

A system, no matter how large or complex, must have an objective, a purpose for being. It will be composed of interrelated elements or subsystems and will consist of an input-transformation-output process. The system, in the context of this thesis, will function as an open system where exchange of information, energy, or material will occur with the environment. The system will have boundaries of operation, even though at times not explicitely defined. The system will have interfaces, both inter- and intra-system and both functional and informational in nature. The system will also have an environment in which to function. Thus the above descriptive narrative is not unlike any organizational system within the T&E system process.

The systems approach provides a systematic way of thinking about the job of management and provides a framework for visualizing internal and external environmental factors as an

integrated whole. It allows recognition of the proper place and function of subsystems. It is important to recognize the integrated nature of specific systems, including the fact that each system has both inputs and outputs and can be viewed as a self-contained unit. It is equally important to recognize that these systems are a part of a larger system.

III. THE TEST AND EVALUATION SYSTEM

A. GENERAL

The Test and Evaluation phase for the development of a weapon system is composed of many organizational subsystems interacting in series and/or in parallel, processing inputs into outputs to obtain some objective. Usually this objective is the timely deployment of a successful weapon system into the Fleet in a cost effective manner. Figure 2 is a much simplified, but representative, model of the T&E process. As such the model displays all the classic characteristics of the dynamic systems model as described earlier. The processing function within the T&E system is not however composed of actions and interactions with definable points of interface. There are role conflicts which tend to stretch out the expenditure of scarce resourses, namely flight test time, and these role conflicts eventually work there way down the hierarchy of organizational systems and subsystems until they reach the point where the scarce resourses are physically managed and expended.

In order to effectively analyze the T&E system and the systems approach to management of T&E the concept of T&E must first be presented. Material within this chapter is either paraphrased or taken directly from DoD Directive 5000.3, CNO Instruction 3960.10, the Navy RDT&E Management Guide, and the Board of Inspection and Survey Aircraft Test Directives.

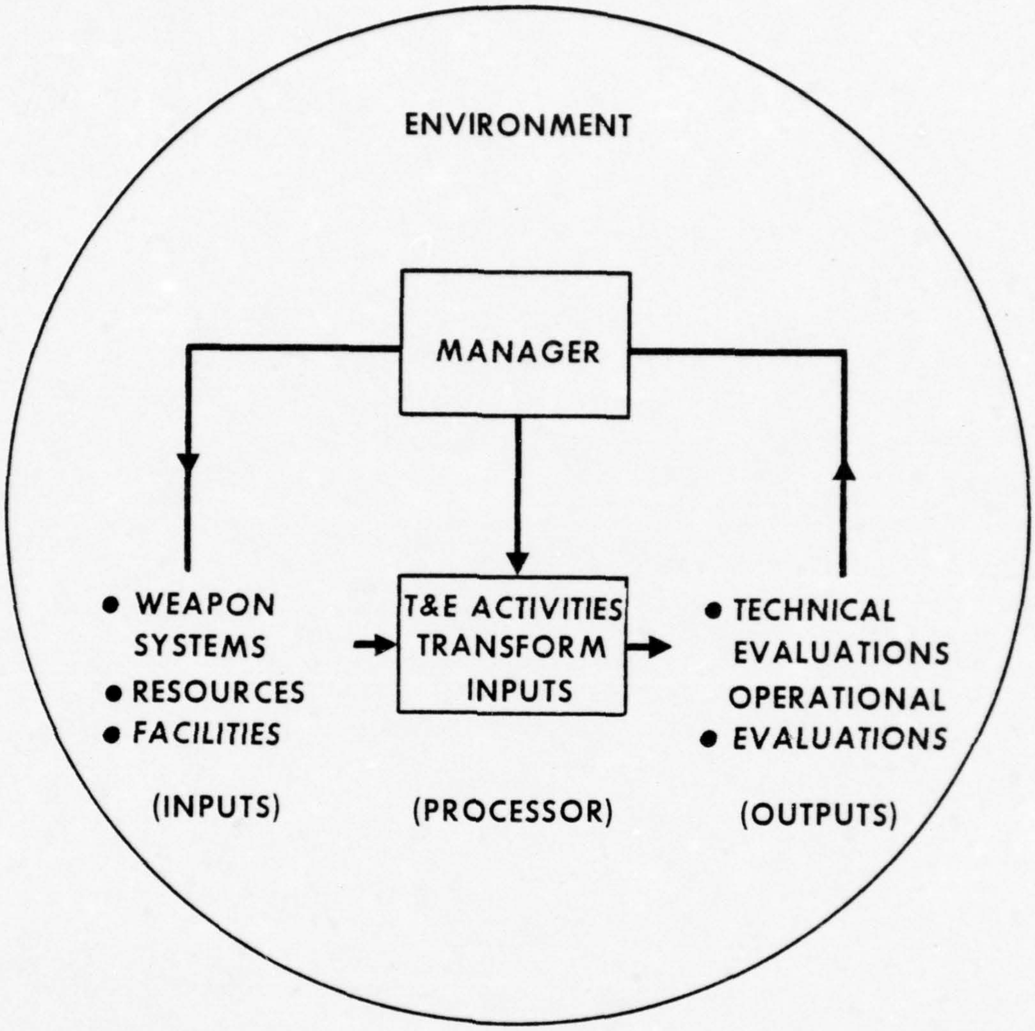


FIGURE 2

MODEL OF THE TEST AND EVALUATION PROCESS

B. TEST AND EVALUATION DEFINED

Test and Evaluation is an all encompassing pair of words which actually have a rather simple yet all inclusive meaning. The following definition of T&E, taken from the RDT&E Management Guide will be used throughout this thesis:

> Test and Evaluation is defined as the performance of tasks and the evaluation of test results which are conducted specifically to:
>
> 1. Support design and development activity.
> 2. Measure performance against specified acceptance criteria.
> 3. Ensure satisfactory operation with related interfacing systems.
> 4. Confirm operational effectiveness and suitability.
> 5. Validate the adequacy of documentation for support and test equipment, personnel training; maintenance and operation of the whole system/subsystems and other elements.
>
> The term "evaluation" denotes the review, analysis, and report of qualitative and quantitative data produced during current or previous inhouse testing, data obtained from tests conducted by other government agencies and contractors, from operational and commercial experience, or combinations thereof.

C. BASIC TEST AND EVALUATION POLICY

Basic T&E policy calls for a development strategy based on periodic performance demonstrations. Programs are to be structured and resourses allocated to ensure that the demonstration of actual achievement of program objectives is the pacing function. Test and Evaluation begins in the earliest phase of RDT&E with experimental testing of scientific hypotheses and continues beyond completion of development where primary emphasis is on perfecting doctrine for the most effective deployment of advanced weapons.

A basic T&E concept is that of the "independent evaluation". Distinction is made between the Developing Agency (DA), i.e. the seller and the operating forces, i.e. the buyer. The DA thus does not have unilateral control of the establishment of test requirements, the conduct of tests, or evaluation of the results. The independent evaluation is performed by OPTEVFOR. Members of this force must therefore perform a key role in determining test requirements and have access to test results obtained by the DA. Evaluation for service use, operational effectiveness, and suitability is performed by OPTEVFOR and as such have a major impact on the acquisition milestone decisions. These decisions are made by the Defense System Acquisition Review Council (DSARC).

The T&E process has recently incorporated the Test and Evaluation Master Plan (TEMP) as a controlling management document. The TEMP defines the test and evaluation plan for each major weapon system acquisition program. It contains the integrated test and resourse requirements of the DT&E, OT&E, and PAT&E agencies and is updated periodically to reflect required changes.

D. TYPES OF TEST AND EVALUATION

Department of Defense Directive 5000.3 and CNO Instruction 3960.10 delineate three basic types of T&E: DT&E, OT&E, and PAT&E, each of which is delegated to a different organization. Figure 3 will aid in illustratin the relationship and time phasing of each system throughout the T&E process.

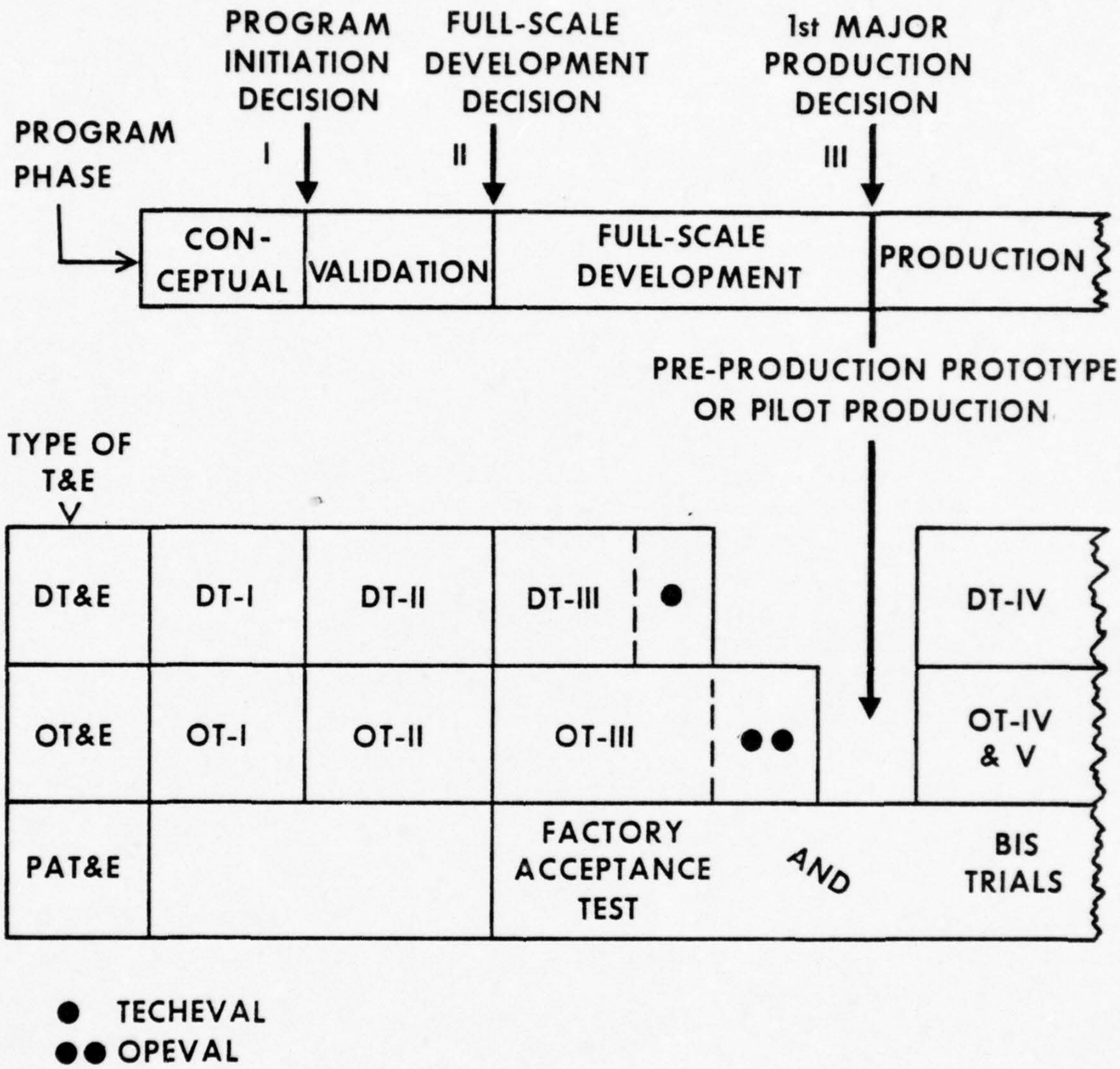


FIGURE 3

RELATIONSHIP OF THE TYPES OF TEST AND EVALUATION

1. Developmental Test and Evaluation

Developmental Test and Evaluation is planned by, conducted by or for, monitored by, and reported by the DA. The DA shall ensure that the DT&E program and the OT&E requirements are integrated into the program schedule and with proper budgeting. Also the DA shall provide OPTEVFOR with all significant DT&E test data. The objectives of this type of test and evaluation are to:

(1) Demonstrate that the engineering design and development process is complete.

(2) Demonstrate that the system will meet specifications.

(3) Demonstrate that the design risks have been minimized.

(4) Estimate the system's military utility when introduced.

Developmental Test and Evaluation is conducted in four major phases. The specific objectives of each phase are developed by the DA and published in the TEMP. The phases are:

(1) DT-I is that DT&E conducted during the conceptual phase to support the program initiation decision.

(2) DT-II is that DT&E conducted during the validation phase to support the full scale development decision. This phase, normally conducted at the subsystem/component level, demonstrates that design risks have been identified and minimized.

(3) DT-III is that DT&E conducted during the full scale development phase to support the first major production decision. This phase demonstrates that the design meets all its specifications. This phase may be further subdivided into other phases such as contractor and Navy technical evaluations. The purpose of the TECHEVAL, the final sub-phase is to verify that the design meets specified requirements and is ready for OPEVAL.

(4) DT-IV is that DT&E conducted after the first major production decision to verify that the improvements or corrections of design deficiencies discovered during OPEVAL, FOT&E, or fleet deployment are effective.

2. Operational Test and Evaluation

Operational Test and Evaluation is accomplished by operational and support personnel of the type and qualification of those expected to use and maintain the system when deployed, and is conducted in as realistic an operational environment as possible. OT&E is planned by, conducted by or for, and reported directly to the CNO by OPTEVFOR. Additionally OPTEVFOR provides the DA with all significant OT&E test data and analysis. The objectives of this type of test and evaluation are to:

(1) Estimate the prospective system's military utility, operational effectiveness, and operational suitability (including compatibility, interoperability, reliability, maintainability, and logistic and training requirements), and need for any modifications.

(2) Provide information on organization, personnel requirements, doctrine and tactics.

(3) Provide data to support or verify material in operating instructions, publications, and handbooks.

OT&E is subdivided into two major categories: Initial OT&E (IOT&E) which is all OT&E prior to the first major production decision, and Follow-on OT&E (FOT&E) which is all OT&E after the first major production decision. OT&E is divided into five major phases (3 IOT&E and 2 FOT&E). The specific objectives

of each phase of OT&E are developed by OPTEVFOR and published in the TEMP. The phases are:

(1) OT-I is any IOT&E that may be conducted during the conceptual phase to support the program initiation decision.

(2) OT-II is that IOT&E conducted during the validation phase to support the full-scale development decision. The objectives of OT-II are to:

(a) Provide an early estimate of projected operational effectiveness and operational suitability of the system.

(b) Initiate tactics development.

(c) Estimate program progress.

(d) Identify operational issues for OT-III.

(3) OT-III is that IOT&E conducted during the full scale development phase to support the first major production decision. OPEVAL is the final sub-phase of OT-III. Specific objectives of this phase include:

(a) Demonstration of the achievement of program objectives for operational effectiveness and suitability.

(b) Continuing tactics development.

(4) OT-IV is that FOT&E conducted after the first major production decision, but before production systems are available for testing. Specific objectives of this phase include:

(a) Testing of fixes to be incorporated in production systems.

(b) Completion of any deferred or incomplete IOT&E.

(c) Continuing tactics development.

(5) OT-V is that FOT&E conducted on production systems as soon as they are available. Objectives of this phase include:

(a) Demonstration of the achievement of program objectives for production system operational effectiveness and suitability.

(b) OT&E of the system in new environments or in new applications or against new threats.

3. Production Acceptance Test and Evaluation

This is test and evaluation of production items to demonstrate that the items procurred fulfill the requirements and specifications of the procurring contract or agreement. This function is carried out by the Board of Inspection and Survey (BIS). BIS is responsible to the SecNav via CNO for conducting tests and recommendations for "acceptance for service use" if test results warrant such. The purpose of these "Service Acceptance Trials" are to:

(1) Discover and report deficiencies at the earliest possible time so that corrective action can be taken to ensure that aircraft delivered to the fleet will be capable of carrying out the intended mission.

(2) Recommend design changes which could improve system effectiveness and identify design features which should be changed or avoided in future designs.

(3) Determine if contract specifications and authorized changes thereto have been satisfactorily fulfilled and render an opinion as the the government's or the contractors responsibility for the correction of defects.

(4) Recommend to the SecNav the conditions of acceptance or rejection of an aircraft for service use.

E. TEST AND EVALUATION SUMMARY

The T&E process is thus presented as a hierarchy of systems all acting within the overall T&E system process. The overall T&E system is composed basically of three large systems, the DT&E, OT&E, and PAT&E systems. Each of these systems have objectives and definitive time phases within the T&E process. Thus the WHO, WHAT, WHY, and WHEN of the T&E process is provided. A typical organization chart of the three systems involved in a weapon system program is presented in Figure 4, and it displays an important concept to recognize in applying the systems approach to management. That is as the T&E system becomes larger and more organizations are involved in T&E due to their specialization the number of systems interface and combinations thereof increase enormously.

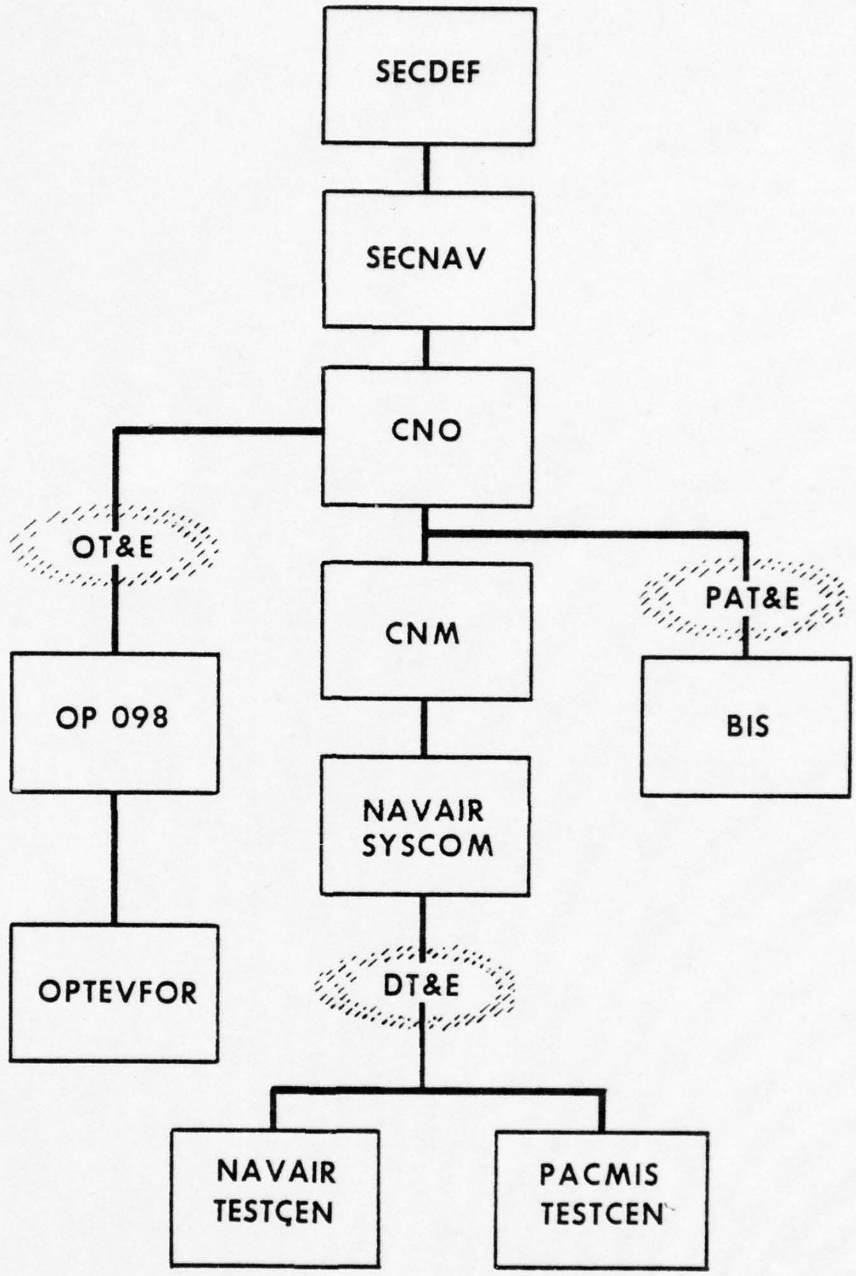


FIGURE 4

ORGANIZATION CHART OF THE SYSTEMS INVOLVED IN TEST AND EVALUATION OF A WEAPON SYSTEM

IV. A SYSTEMS LOOK AT THE TYPES OF TEST AND EVALUATION

A. GENERAL

Modern T&E has come a long way from the scarf and goggle days of screaming power dives and high-g pull outs. Technology in data acquisition systems and analysis procedures have kept up with the ever increasing weapon systems technology and complexity. The T&E process has grown from one lieutenant performing all flight tests on a system to several different and distinct organizations performing flight tests on a weapon system such as the F-14 or F-18 airplanes. Growth and sophistication of the T&E process has not however been without problems. Committees and directives have provided guidelines and direction, but this growth has often created significant problems; problems which ultimately mean inefficient and ineffective use of T&E scarce resourses. The following sections attempt to reconstruct some of the more recent and significant adverse factors affecting the overall T&E process.

Recent theses by H. L. Young, Jr. [NPG Thesis, 1973] and W. C. Bowes [NPG Thesis, 1974] studied many aspects of the overall T&E process as relating to F-14 managerial problems and to the organization of T&E in general. Some of their findings and conclusions are included in the following sections to add more substantiation to the managerial factors affecting T&E.

The following sections are organized into the types of T&E performed on a weapon system; DT&E, OT&E, and PAT&E. Each

of these systems are subsequently divided into subsection of objectives, inputs/outputs, interfaces, system environment, and effectiveness, significant elements which comprise the systems approach. A later chapter will look at the three systems together in the total T&E process system and the associated objectives and interfaces.

B. DEVELOPMENTAL TEST AND EVALUATION

The functions and operation of DT&E have been in existence since the first tests were conducted on a Navy airplane. Their objectives, interfaces, and environment have evolved through time and can be considered as "lodged in concrete" in many instances. Figure 5 provides a schematic model which will aid in the following "systems analysis" of DT&E. The four small circles represent systems which are elements of the larger DT&E system. The DT&E system is existing in the environmental conditions as depicted on the figure. The arrows of the individual systems are intended to signify only relative direction of objectives with respect to each other and not magnitude, rate, or velocity.

1. System Objectives

The objectives of a DT&E organization are usually well defined and parallel those listed under paragraph III-D-1. Each T&E activity and Directorate within the activity has mission statements and/or objectives of the organization listed. Additionally, work units from NAVAIRSYSCOM or other higher organizations supply specific direction and objectives for specific

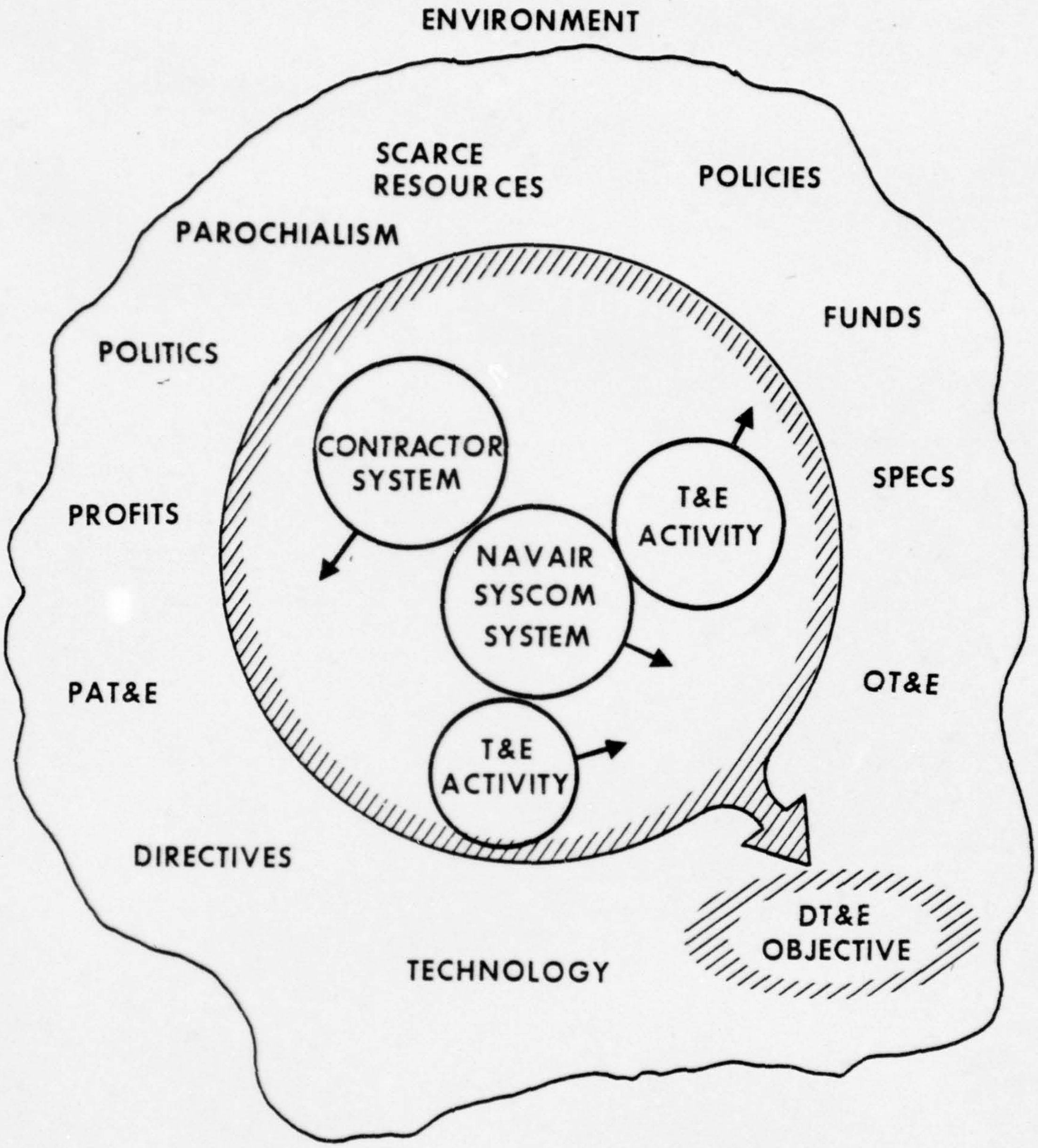


FIGURE 5

MODEL OF THE
DEVELOPMENTAL TEST AND EVALUATION SYSTEM

projects. Finally, test objectives of the weapon systems exist in the form of specifications and performance guarantees.

Note that Figure 5 implies that the elemental subsystems comprising the DT&E system may have objectives in varying directions with respect to each other. Herein lies the major problem that the T&E process must face and will be treated in the next chapter.

2. System Inputs/Outputs

The inputs of the DT&E organization are well defined in terms of funds, personnel, and test resourses such as test airplanes or airplane subsystems. However the inputs may or may not be consistent with the overall objectives of the program in concern. For instance, funds may not be adequate or test airplanes may not be properly configured to make meaningful tests.

Outputs of the DT&E system are usually reports of test results. Timeliness and content of reports have been reported as areas of significant concern. Young [Thesis, 1973] and Bowes [Thesis, 1974] reported that project managers felt that T&E reports are often submitted too late for timely program decisions. Additionally, data submitted during developmental phases, such as the contractor bi-weekly or bi-monthly reports were submitted six to eight weeks after being generated, often too late for effective utilization.

The problem of un-timely data occurs for several reasons. One reason is the scope and complexity of required tests and data acquisition and handling problems. A second is the lack

of feedback and dialogue. Another is the existence of the review chain, a necessary evil in the promulgation of a T&E report. It is the authors view however that the major reason may be because of the lack of understanding or acknowledgement of the role that the DT&E activities play in the overall T&E process. Each output report becomes a cog in a wheel somewhere higher up the T&E organizational hierarchy. It is incumbent on the management of the lower systems to realize that they play a significant part (however small) in the overall process and their system outputs must be timely to be effective.

3. System Interfaces

System interfaces occur where there is direct interaction between two or more different systems or where there is an information flow from one system to another. As expected, the T&E process is composed of many interfaces. There are interfaces between DT&E, OT&E, and PAT&E. And within DT&E there are interfaces between the T&E activities, the contractors, and NAVAIRSYSCOM. For instance, T&E of the F-14 was composed of elements of activities such as NAVAIRTESTCEN, PACMISTESTCEN, and the contractors. Two major problems exist in this area of concern; role conflicts between T&E systems and system parochialism.

Role conflicts exist because of inadequately established objectives or mission statements or because testing of a weapon system is done by two or more different activities separated by large geographic distances. Role conflicts arise from the historical evolution of the various activities. Each activity

in time builds up an expertise based on what their overall mission is and what they perceive is required to accomplish that mission. Thus conflicts arise on who tests what, and the results is usually redundant testing.

In the weapon system area of the F-14 program this conflict was addressed and a Joint Evaluation Team (JET) was formed consisting of members from BIS, NAVAIRTESTCEN, PACMIS-TESTCEN, and from the OT&E community. The JET proved successful to some extent (only within the DT&E community) but conflicts within DT&E activities still existed. The root of the evil could be attributed to the syndrome known as parochialism.

As reported by Young [Thesis, 1973] the self-serving parochial attitude sometimes motivated the actions of organizations participating in the F-14 T&E. This syndrome is difficult to document and validate, and some feel that a certain amount of parochialism is good, that it creates a competitive spirit among T&E systems. But the important point to remember about parochialism is that it seems to breed mutual distrust between organizations, thus curtailing efficient and effective pursuit of overall objectives. Role conflicts and parochial attitudes are caused to some extent by a lack of understanding of "who you are", what function do you play in the overall T&E process; and a general lack of concern for the primary objectives.

Interfaces must exist for the T&E process, but boundaries of each system must be recognized and respected to minimize role conflicts and parochialism before the interfaces can be effective. This means that the individual system objectives

must be established as to purpose and scope such that a interrelated systematic network of systems can be established with appropriate interfaces.

Interfaces are facilitated by the well known "list of key personnel", but this list does not itself establish successful interaction and interface. A system must first recognize that interface with other systems is necessary to meet the objectives of that system and of the objectives of the total system. This system must then establish interface with others, or a linking within the T&E system.

4. System Environment

A primary function of the system is to recognize that the system exists within an environment. This environment changes, either dynamically or turbulently in nature and the system must react and adjust to survive. For the DT&E s[illegible] the environment consists of such things as top management [illegible] available funds, directives, OT&E requirements, and PAT&E requirements to mention only a few. The manager of the system guides the system and controls its destiny, but the environment directs and controls the manager.

5. System Effectiveness

As previously stated, system effectiveness is a measure of how well the objectives of the system have been met. Thus an effective DT&E system is one which performs its mission and meets its objectives. More importantly however the author suggests that an effective DT&E system is one which meets its objectives in the context of the total T&E process. The system

views its function as a part of an interrelated group of T&E systems performing a function to meet the overall objectives of the T&E process of the weapon system in concern. An important factor missing in this context is an evaluation criteria. How well must a system perform or meet its objectives to be effective?

A similiar situation exists when a T&E system is testing a weapon system. Criteria for measuring weapon system effectiveness are supplied in the form of specifications and guarantees. Note however that the fact that a weapon system may meet all the specifications does not guarantee an effective system. This is not a problem of objectives not being stated; but is a problem of the objectives being erronously stated or misinterputed.

It is well recognized that system effectiveness in the T&E world, whether involving a management or a weapons system, is not easy to evaluate. A weapon system has the potential of being numerically evaluated thus providing some measure of effectiveness. The author feels however that the evaluation of a management system is a subjective factor, one that requires rationalization by the manager and a view of the whole instead of a view of individual parts.

C. OPERATIONAL TEST AND EVALUATION

The functions and operations of contemporary OT&E have just recently evolved (since 1971) and hence are short on tradition but long on directive policies. The OT&E primary function of

"independent evaluation" has been both praised and criticized hence their place in the overall T&E process is worthy of analysis. Figure 6 will aid in the following "systems analysis" of OT&E.

1. System Objectives

The objectives of the OT&E system are, as in DT&E, well defined and parallel those listed under paragraph III-D-2. Each activity within OT&E, such as AIRTEVROR FOUR (VX-4), have specific objectives such as to perform OT&E on fighter aircraft systems. Another squadron, VX-5, performs OT&E on attack aircraft systems. However, one of the deficiencies within the overall T&E process as reported by Bowes [Thesis, 1974] is the "lack of adequate OT&E test objectives". This problem still exists and is further amplified because of the lack of adequate criteria for which to design test scenarios; specifications and guarantees do not exist for combat profiles or for operations conducted in war zones.

2. System Inputs/Outputs

The OT&E community has much the same problems as the DT&E community with respect to funds, personnel, airplanes, and reports. Peculiar problem areas to OT&E however lie in the area of airplanes and personnel.

Being operationally oriented necessitates the use of production configured airplanes. This unfortunately is not always possible in the T&E process until far down the development cycle. Hence a true operational assessment of a weapon system cannot be made until dangerously close to the milestone

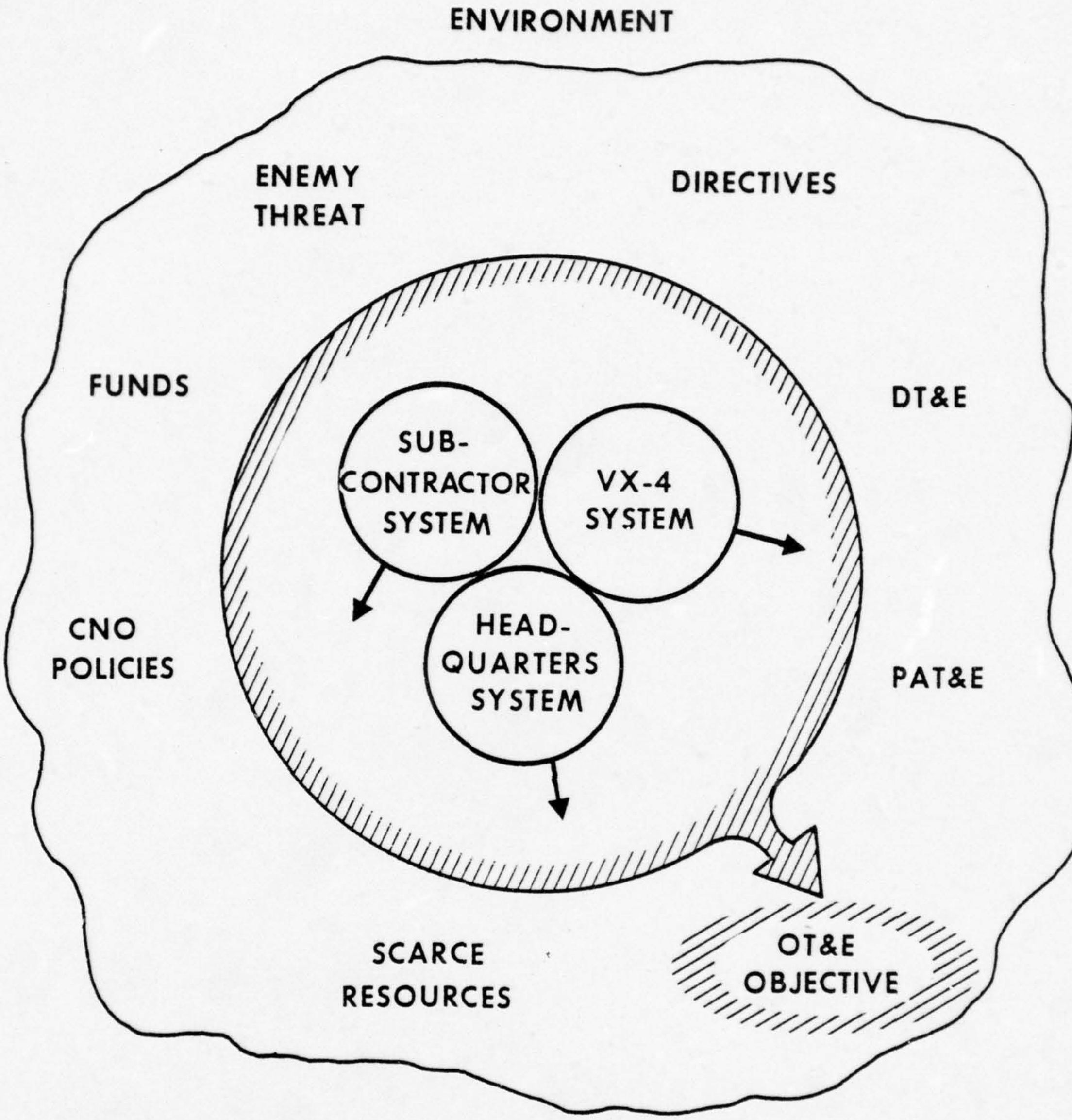


FIGURE 6

MODEL OF THE
OPERATIONAL TEST AND EVALUATION SYSTEM

for major production decision. The role and objectives of OT&E are thus difficult to achieve in a strict sense. Of necessity, flying has to be performed on prototype airplanes with systems possibly still in development. The final production configured airplane may not be the same as tested by OT&E.

Lack of analytical and technical personnel is another factor adversly affecting the function of OT&E. Program planning and data analysis support is currently being performed by non-airframe type contractors working under the control of OPTEVFOR. This is expensive and undersirable in some respects. These functions could just as well be performed by civil service engineers with the appropriate expertise.

3. System Interfaces

Interfaces within the OT&E system are primarily with the squadrons, Headquarters, DT&E activities, and the contractors who perform data analysis. An apparent interface problem, as perceived by this author, may lie within the interface of Headquarters and the squadron level. This is a result of possible differences of opinion as to the interpretation of the stated objectives. An educational and/or communicational in-house process can rectify the situation.

A unique interface problem facing OT&E is the dilemma of when to get involved in the T&E of the Weapon system. Too early an entry may mean disruption of the developmental process and may involve a prototype airplane non-representative of the production lot. Too late an entry and OT&E will have little or no input on the major production decision and suitability

for fleet operation. The author perceives internal conflict within DoD on the exact role of OT&E and further still, the author perceives conflict within the OT&E community itself on what it's role is to be.

4. System Environment

The environment that OT&E operates within is much like that of DT&E. The major factors being CNO policy/directives, DT&E, PAT&E, funds, and test aircraft availability. The OT&E system too must recognize that the environment exists and is ever changing in order to survive.

5. System Effectiveness

As with the DT&E system, the effectiveness of the OT&E system is a function of how well the system meets its objectives and how well it fits into the interrelated group of other T&E elements. Managerial effectiveness can be attained by recognizing this, just as with any other T&E activity.

The major problem lies in the lack of test objectives and criteria for determing the effectiveness of the weapon systems themselves when evaluating in an operational environment. A test program should be designed to measure the suitability or effectiveness of a system against some criteria which may either be supplied by an Operational Requirement or Detailed Specification. An operational effectiveness criteria is needed for which the OT&E system can evaluate the results of their tests.

Thus the objectives of OT&E are stated, but the missing ingredient is a test criteria. The criteria of "mission

suitability" is well and good but different pilots have different views as to what is suitable, and more importantly, different abilities to evaluate the system. By the "seat of the pants" is not good enough, hence the effectiveness of the weapon system is at best a subjective evaluation. This problem is however not unique to OT&E. The DT&E community is hard pressed to evaluate system effectiveness as previously discussed. Meeting or exceeding a specification number does not make the system effective. Apparently the weapons planners do not know enough yet about threat forecasting and combat effectiveness criteria to tie a number to it, and understandly so; the environment for which the system is designed changes constantly.

D. PRODUCTION ACCEPTANCE TEST AND EVALUATION

The functions and objectives of PAT&E have evolved along with DT&E throughout the years and are carried out by the BIS. Figure 7 will aid in the analysis of the PAT&E system.

1. System Objectives

The objectives of PAT&E as carried out by BIS are those listed under paragraph III-D-3 and need not be reiterated here. Primarily the role of BIS is that of recommending conditions of acceptance or rejection for service use of a weapon system. This is done by providing timely inputs of technical aspects of the weapon system to SecNav via CNO. These objectives have been with the total T&E process for some time and tend to assure an overall satisfactory weapon system for the fleet. Additionally, test objectives exist in the form of specifications and guarantees for which the weapon system must meet.

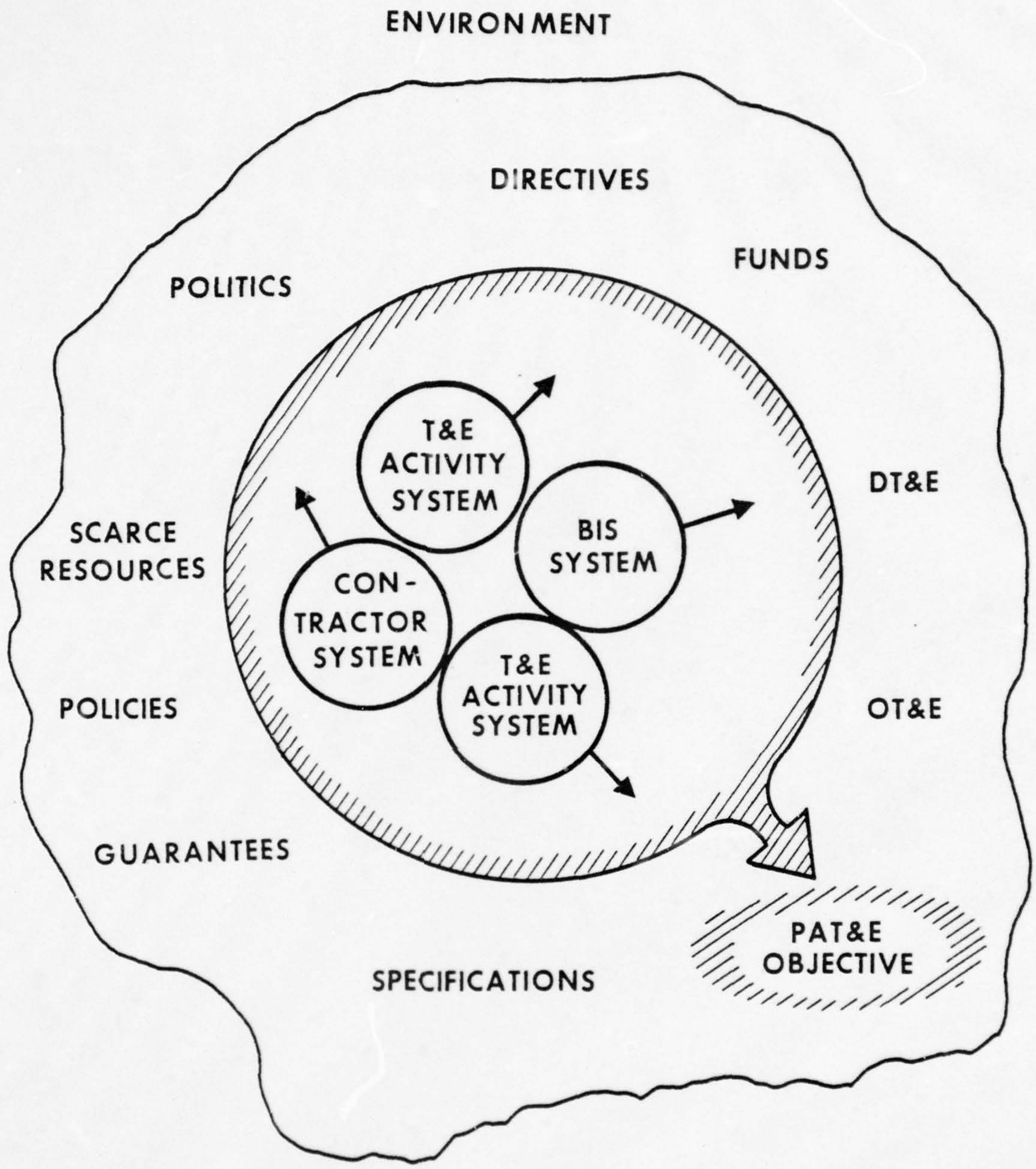


FIGURE 7

MODEL OF THE PRODUCTION ACCEPTANCE
TEST AND EVALUATION SYSTEM

2. System Inputs/Outputs

Inputs for the PAT&E system include airplanes, funds, and T&E activities. The BIS tasks appropriate T&E activities to determine compliance with weapon system requirements. Personnel from these T&E activities in effect become a member of the "BIS team" and actually work for the Board. Funds and aircraft are requested from NAVAIRSYSCOM by BIS who then gains control of these assets.

The outputs from BIS consists primarily of individual "Yellow-Sheets" which describe specification and/or mission deficiencies of the weapon system and must be supported by substantiating data. These "Yellow-Sheets" are followed up with a formal all inclusive report which is endorsed through the hierarchy to the SecNav.

3. System Interfaces

Interfaces within the PAT&E system are much the same as in the DT&E system with the exception that the "Board" is a primary elemental organization. Note that BIS itself is not a testing agency or testing complex per se, it is a reporting agency. The existing T&E activities and facilities do the work for BIS as BIS members and report test results in required form to the President of the Board who in turn reports to SecNav via the CNO.

4. System Environment

The environment of PAT&E is much like that of DT&E and OT&E. The primary factors being CNO policy, funds, test airplanes, and the individual T&E activities.

5. System Effectiveness

Effectiveness of the PAT&E system can be evaluated in terms of how well it meets its objectives previously discussed. The problem is that no one knows the deficiencies and/or problems that are not discovered, only those that are discovered. Hence the effectiveness of the PAT&E system may be a measure ultimately of successful fleet operation. If the weapon system functions well, then the entire T&E process has been performed well. If deficiencies are discovered by the fleet during operations that something faultered during the T&E cycle. Of course these are again subjective areas of discussion and again the point of evaluation effectiveness of a T&E system is a difficult one to attempt.

E. SUMMARY OF THE TYPES OF TEST AND EVALUATION

The preceeding sections have presented a systems view of the three types of T&E; DT&E, OT&E, and PAT&E, each of which have established objectives. However these three systems are comprised themselves of many lower order systems which in many cases may have objectives not in congruence with the larger systems objectives. The salient point is however that each system can be analyzed in terms of typical systematic characterisitcs of the dynamic systems model, i.e. objectives, inputs and outputs, interfaces, environment, and effectiveness.

V. A SYSTEMS LOOK AT THE TOTAL T&E PROCESS

The three types of T&E have been analyzed using a systems approach. Each individual system has its fundamental elements and systematic characteristics. But the T&E process must be viewed as a whole instead of as individual parts. The systems of DT&E, OT&E, and PAT&E are all interrelated elemental systems of the whole T&E system process.

The T&E process within the Navy is currently in a flexing posture. New policies and trends coupled with stricter control over scarce resourses triggered by the economical and political environments are impacting T&E significantly. Rapidly advancing technology in both the weapon systems themselves and the media and methods for conducting T&E are adding to the complexities of T&E today. A systems look at the total T&E process as it exists now is warranted, for it illustrates several significant problems and areas of conflict. The recent experience on the F-14 weapon system and some of the experience to date of the F-18 program offer evidence that some systematic approach is indeed needed. Figure 8 is presented to depict the current environment and turmoil within the T&E system and to aid in understanding the succeeding paragraphs. The objectives, interfaces, and effectiveness features of a dynamic system are again used to analyze the total T&E process. The input/output and environmental dimensions are not presented here because they expand the systems study to the Congressional level and impose

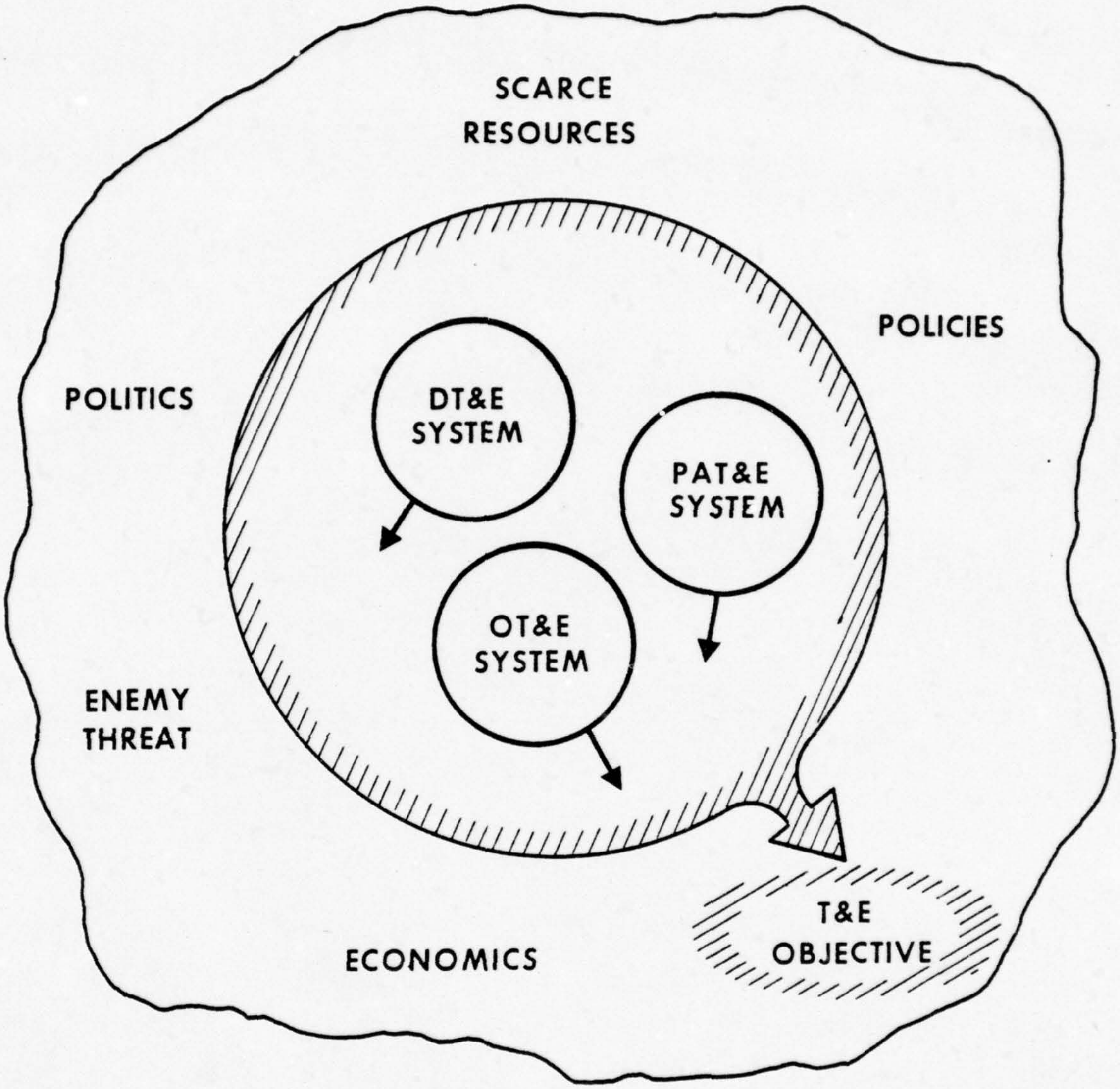


FIGURE 8

MODEL OF THE TOTAL TEST AND EVALUATION SYSTEM

correspondingly immeasurables upon the study such as bureaucratic politics. This expansion, although certainly valid, is not needed to put forth this thesis.

A. SYSTEM OBJECTIVES OF T&E

The objectives of DT&E, OT&E,and PAT&E have been listed and discussed in the preceeding chapter. This section presents the objectives of the total T&E process. In simplistic and condensed form, the primary objective of T&E is to perform tasks and evaluate test results which are conducted to:

(1) Support design and development activities.

(2) Measure performance against specified acceptance criteria.

(3) Confirm operational effectiveness and suitability.

(4) Ensure satisfactory operation with related interfacing systems.

(5) Validate the adequacy of documentation for support and test equipment, personnel training; maintenance and operation of the whole system/subsystem and other elements.

Note that objective (1) corresponds to DT&E functions; objective (2) to DT&E and PAT&E; and objective (3) to OT&E and PAT&E. Objectives (4) and (5) are unfortunately sometimes not addressed, either because of ignorance or of constraints on the total flight test program itself such as lack of a fully configured aircraft. Thus the overall objectives of T&E are separated into the three types of T&E systems. The subsequent integration of these objectives toward the whole system objectives are sometimes overlooked.

B. SYSTEM INTERFACES WITHIN T&E

The elemental systems comprising the T&E system which interface with each other consist of the DT&E, OT&E, and PAT&E systems as presented in the previous chapter. As evidenced in Figure 8 these systems are, unfortunately, not always interrelated into a cohesive whole necessary for effective T&E. Role conflicts exist between the systems and some guidance, direction and/or framework for thinking must be implanted in the T&E process to minimize this inefficient use of scarce resourses.

Several areas of conflict within the F-14 T&E program were documented by Young [Thesis, 1973] and are summarized here. One area of conflict is between the DT&E and OT&E systems. The crux of the problem lies within the question of when should OT&E become involved in the overall T&E process, if at all. One argument says that little OT&E is needed since the DT&E community is able to conduct tests with an objective, independent approach by operationally experienced flight crews, just as OT&E does. There are fears that OT&E can disrupt the DT&E process with too early an involvement and also be counterproductive to the OT&E objectives because the airplane systems configurations are usually not stabilized until far downstream in the T&E process.

The OT&E community feel, of course, that their involvement in the T&E process is necessary, for that is their purpose in being. The primary concern of OT&E is apparently not one of early involvement, but one of adequate and timely involvement prior to the first major production decision milestone. Too

meet their objectives the OT&E phase needs calender time within the DT&E process and dedicated test airplanes configured as close as possible to production configurations.

Another area of conflict is between PAT&E and OT&E. Both systems report to CNO on the adequacy of the total weapon system. The OT&E system reports on "adequacy of service suitability" while PAT&E (BIS) reports on "acceptance for service use". Even though the OT&E system reports on operational effectiveness and PAT&E reports on technical effectiveness both realistically offer the objective opinion of whether the system is ready for the fleet. However the OT&E system reports directly to CNO throughout the T&E process while PAT&E does not report until further downstream the T&E process. The OT&E system is thus visible to CNO somewhat before the PAT&E system. The F-18 program currently has BIS scheduled after the first major production decision milestone, certainly contradictory to the objectives of PAT&E. The BIS recognizes that the PAT&E system has little effect on the major production decision process if the T&E system exists as described. Hence BIS needs an "initial" look at the weapon system in order to function consistently within their stated objectives. This "Initial Trials Phase" has long been in existence and should remain actively so such as to allow BIS timely meeting of its objectives.

C. SYSTEM EFFECTIVENESS

As previously discussed, effectiveness is a subjective parameter in the T&E world. The individual T&E subsystems,

(DT&E, OT&E, and PAT&E) strive to meet the stated objectives of their respective systems and a subjective statement as to the adequacy of meeting those objectives can be made. Each system acts within its own environment and functions accordingly.

The effectiveness of the total T&E system is just as illusive as that of the individual systems comprising T&E. The effectiveness of the T&E system as a cohesive whole is in question. Evidence to date indicates that the T&E system is low in effectiveness because of existing conflicts which tend to detract from the overall goals and waste significant amounts of scarce resourses. The F-14 JET concept was an example. The JET was formed to integrate all testing requirements. All three T&E systems were involved but only the interface of DT&E/PAT&E was fluid (and only to a minimal degree). The objectives of the JET, as viewed by DT&E, were to satisfy the BIS requirements. The means to the end were however interpretated differently by the various individuals within the DT&E system. The OT&E system, even though involved "on paper" within the process, was not readily accepted. Hence their objectives fell by the wayside. Thus the objectives of the JET concept, to unite the T&E systems, failed.

There are some indications that the future F-18 program is encountering conflicts within the total T&E system. Of significance is the situation within DT&E and the T&E activity subsystems where the missile expertise of the weapon system are not currently actively participating within the DT&E process.

Conflict is good, too a degree. Without conflict certain points of view and alternatives would not be fostered. However the result of conflict within the T&E process is rapid, needless expenditure of the most significant resourse for T&E, namely flight test time. Conflict must be controlled so that the total objectives of the T&E system are visible, and each of the subsystems within the T&E system align its respective objectives to the primay objective of the total system. The T&E system must be composed of interrelated parts acting as a cohesive whole following a given logical sequence. The three systems are interdependent on each other for effective overall T&E of a weapon system.

D. SUMMARY OF THE TOTAL T&E PROCESS

The total T&E system process is comprised of the DT&E, OT&E, and PAT&E systems. Even though the systems have complementary stated objectives (in directive form) their actual behavior is such that one might conclude that the objectives of these systems are not really complementary and do not act in total alignment with the objectives of the T&E process. Role conflict and parochialism exist and each system must recognize its part in relation to the whole before an effective T&E system can exist.

VI. THE SYSTEMS APPROACH TO MANAGEMENT AND THE T&E PROCESS

Thus far this thesis has established that the T&E process is in fact composed of three large systems interacting to perform the test and evaluation function. These larger systems, the DT&E, the OT&E, and PAT&E systems are themselves composed of many lower order systems. It has been shown that all these systems, including the T&E system itself, displays the systemic characteristics of a dynamic system. The concept of the systems approach to management has been put forth and the importance of viewing the system as a whole has been stressed. As previously pointed out, before the manager of a T&E system can effectively manage he must know the process of his system and its role in the overall T&E system.

A. MANAGEMENT AND THE TEST AND EVALUATION PROCESS

The management functions within the T&E process can be better understood if the T&E system is further analyzed. Chapters III through IV have discussed the types of T&E from a systems view. T&E can also be analyzed by looking at its various phases. As outlined by Perry [1976] in discussing the role of T&E, the T&E process consists of five basic phases:

(1) Planning

(2) Programming

(3) Budgeting

(4) Testing

(5) Evaluation

A good manager relies on ideas, resourses, things, tools, and people to achieve objectives. He utilizes such managerial functions as planning, organizing, staffing, directing, and controlling as prescribed by such authors as Koontz and O'Donnell [1968]. More importantly these functions must be harmonized and put in juxtaposition with the five basic phases of T&E. This correlation is depicted in Figure 9 which shows the relationship of basic managerial functions to the basic phases of the T&E process. Perry describes the basic phases of T&E in the following manner.

During the planning phase the role of test and evaluation is to work for, work with, and provide feedback to the planning arm of the organization. As such, seven steps are required of the manager for the planning function:

(1) Understand the need of the program manager.

(2) Set test and evaluation objectives in harmony with the program objectives.

(3) Develop time phasing for entire life cycle of the program.

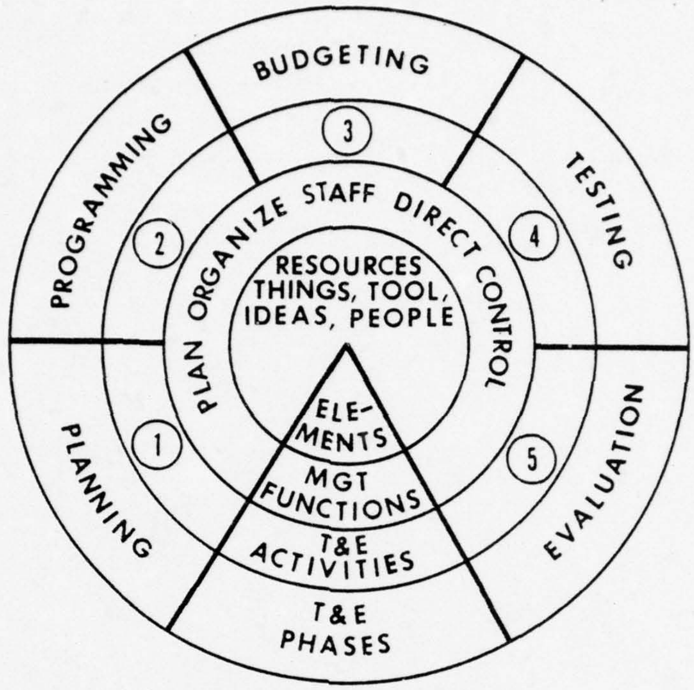
(4) Establish test program goals and milestones.

(5) Select appropriate procedures and methods to be applied during T&E.

(6) Construct a test and evaluation master plan which is documented transmittable to other organizations as a TEMP.

(7) Share with other managers in formulating the strategies, tactics and policy to achieve success of the program.

The programming phase is concerned with a quantified definition of what work has to be done and what work resourses



T&E ACTIVITIES

1. PLANNING
   - UNDERSTAND NEED
   - SET OBJECTIVES
   - TIME PHASING
   - GOALS AND MILESTONES
   - SELECT METHODS
   - CONSTRUCT TEMP
   - DEVELOP POLICY

2. PROGRAMMING
   - ESTABLISH T&E STRUCTURE
   - DELINEATE WORK RELATIONS
   - PRICE WORK RESOURCES
   - CHOOSE BEST PROGRAM

3. BUDGETING
   - ALLOCATE QUALITY
   - DETERMINE QUANTITY
   - APPORTION TIME
   - BUDGET MONEY

4. TESTING
   - FORMULATE CRITERIA
   - DESIGN THE EXPERIMENT
   - FIRM THE TEST MODEL
   - CONDUCT TESTS
   - ANALYZE DATA

5. EVALUATION
   - SYNTHESIZE DATA
   - COMPARE TO CRITERIA
   - DERIVE RESULTS
   - REPORT
   - SHARE IN RISK

FIGURE 9

RELATIONSHIP OF MANAGERIAL
FUNCTIONS TO THE PHASES OF TEST AND EVALUATION

will be necessary to accomplish a viable test and evaluation program. The basic managerial functions of organizing and staffing are important for this phase; as such there are four basic steps:

(1) Establish the test and evaluation work structure by making sure that all the system elements (both vertical and horizontal) are properly put in perspective as to what tests and what evaluations must be performed.

(2) Delineate the work relationship by identifying how the human element and the organizations (internally and externally) will perform the structured work.

(3) Price the work resourses by estimating the costs and benefits to be provided by test and evaluation.

(4) Choose the best program alternative and provide a feedback to the program manager for his acceptance.

The budgeting phase follows planning and programming. The test and evaluation organization must be concerned with the quality level of the product, the quantity of T&E information to be generated, the quantity of resourses to be applied in reaching the desired level of confidence regarding critical unknowns and these into explicit schedules. This permits the monetary and financial budgeting requirements for the total T&E program. As such, four basic steps concerned with allocation of the budget are:

(1) Quality

(2) Quantity

(3) Time

(4) Money

The pattern of the testing and the evaluation functions are derived from the scientific approach of management. During the testing phase five activities are required:

(1) Formulate the evaluation criteria.

(2) Design the experiments.

(3) Identify exactly how elements of hardware, software, and "brainware" will be integrated during the test program.

(4) Conduct the tests.

(5) Analyze and process the required data.

The evaluation phase continues the testing process by accomplishing five more steps:

(1) Synthesize the data obtained from testing by making sure that the information is relevant, germaine, and valid.

(2) Compare the synthesized data with performance standards and the evaluation criteria.

(3) Derive the results required by management.

(4) Report the results in language useable and understandable by management.

(5) Provide recommendations as to confidence and overall risk of the system or product.

Collectively this is a closed loop process which relies on ideas, resourses, things, tools, and people. Such a test and evaluation process model can serve the T&E manager as a checklist of systematic and sequential steps within his organization. In the T&E system the manager must recognize that the objectives to meet through use of resourses, ideas, and people are the ones consistent with the "whole" T&E process, which itself

consists of the basic phases of planning, programming, budgeting, test, and evaluation. The manager must also not loose site of the fact that the T&E system is merely a subsystem itself. T&E is a managerial tool to be used to provide information necessary to make development, procurement, and deployment decisions.

B. STRATEGY FORMULATION - IMPLEMENTATION OF THE SYSTEMS APPROACH

The task of how to implement the systems approach to management becomes an important issue, for merely talking about the concepts and methodology will not create action. This approach, once its validity and usefulness have been recognized, must be implemented. Implementation can be made to any system for each system is independent as to "how" it is managed. Systems are not independent as to "how" they function, for each has interrelated elements forming a whole. A lesson from the corporation world on the concepts of strategy is worthy of note.

The systems approach to management may be initiated by applying the concepts of strategy formulation practiced by many corporations. Corporate strategy can best be defined, according to Uyterhoeven [1973] by looking at the purposes it serves; to provide both direction and cohesion to the enterprise. Providing direction is the traditional objective of corporate strategy: to give the company a sense of purpose and mission. Providing cohesion is however more essential than providing direction. In providing cohesion, corporate strategy influences the unit strategies rather than permitting the latter to shape the corporate response. Furthermore, to

establish cohesion corporate strategy must establish priorities among the units. Finally cohesion requires that the activities of the various units be interrelated. This integration aspect not only provides a common sense of direction to the units but also permits the total organizational response to be more effective than that of the sum of its parts. These concepts from Uyterhoeven about corporate strategy are readily applicable to any T&E organizational system. The model developed by Uyterhoeven to formulate strategy is presented below with amplifying statements showing the relationship to the T&E process. The formulation of corporate strategy encompasses seven steps:

(1) Develop a Strategic Profile which concerns itself with the business or objectives of the system.

(2) Evaluate the Environmental Dimension, including such factors as politics, economics, and technology.

(3) Arrive at a Strategic Forecast which relys on the validity of the environmental analysis. This concerns itself with predicting the future shape or posture of the environmental dimension.

(4) Perform a Resourse Audit which focuses on the internal dimensions. Resourses are identified and evaluated and the strengths and weaknesses of the organization are developed.

(5) Develop Strategic Alternatives which concerns itself with how can the organization respond to a given stimuli, what are the range of choices for meeting an obligation or objective.

(6) Perform a Test of Consistency which relates what the system or organization is "able" to do with respect to its available resourses to what is "possible" in its given external environment.

(7) The manager makes a Strategic Choice of the available alternatives which provide consistency within the stated goals or objectives.

The author must however caution the readers not to oversimplify the issues just discussed. Implementation of a "corporate strategy" which in turn initiates the application of the systems approach to management may meet unsurmountable obstacles. These implementation problems are discussed by Allison [1971] in his analysis of the "Cuban missile crisis". In essence, the rational alternatives and choices arrived at may be strongly affected by organizational policies and bureaucratic politics, either adversely or reinforcingly, depending on the situation and the people involved.

C. SUMMARY

The systems approach provides the manager with a framework for thinking about the job of management. Coupling this approach with the systematic nature of the T&E process offers an ideal tool for the manager to use. The classic functions of management can be kept in juxtaposition with the phases of T&E to provide a better insight to management within the T&E process. Implementation of a strategy is perhaps the most important first step in practically using the systems approach and as such stimulates the manager to think in the proper perspective.

VII. CONCLUSIONS

This thesis has developed two basic conclusions as a result of utilizing a dynamic systems model to analyze the Test and Evaluation process. The first is that the Test and Evaluation process can be represented as a conglomerate of lower-order systems. Each layer of systems can be characteristically analyzed by focusing on the objectives, input/outputs, interfaces, environmental, and effectiveness dimensions.

The systematic characteristics of the Test and Evaluation process suggests that a systematic approach to management can be readily applied by managers. This thus constitutes the second basic conclusion of this thesis. A paradigm for the Test and Evaluation process, useful in many respects, is the systems approach to management. This approach provides the managers a systematic approach to the job of management, one which the author finds appealing to the engineering background. This framework of thinking guides the manager to view the whole instead of only his elemental part. More importantly the manager will recognize the importance of properly aligned objectives. The formulation of a strategy becomes important in implementation of this paradigm for it provides the means to initiate this approach to management and it provides the groundwork for direction and cohesion so needed by the system.

APPENDIX A

ORGANIZATIONS WITH WHICH INTERVIEWS WERE CONDUCTED

Developmental Test and Evaluation

1. Naval Air Test Center, Patuxent River, Md.
2. Pacific Missile Test Center, Pt Mugu, Calif.
3. Air Force Flight Test Center, Edwards AFB, Calif.
4. Naval Air Systems Command, AIR 5102 Office, Wash. D.C.

Operational Test and Evaluation

5. AIRTEVRON FOUR (VX-4), Pt Mugu, Calif.

Production Acceptance Test and Evaluation

6. Sub Board of Inspection and Survey, Patuxent River, Md.

APPENDIX B

EVOLUTION OF THE VARIOUS MANAGEMENT THEORIES

A. INTRODUCTION

The systems approach to management is one of the many theories of management that exist today. There are however some clearly identifiable concepts which provide a systematic look at these various theories. The following paragraphs [Luthans, 1973] and Figure 10 provide an aid in understanding these theories and their relationship to each other.

The starting point of management theories can be traced to Henri Fayol. In 1916 he identified the universal functions of management as processes of planning, organizing, commanding, coordinating, and controlling. Fayol's work did not however become the mainstream of management theory until the 1950's. His process theories have remained relatively intact, however some of the terminology has changed. Fayol's "commanding" process is now known as "directing". Dispite the changes in terminology and principles the universality assumption of the process approach is still made and remains as the theoretical base for management.

In recent years the process approach has been overrun by other theoretical approaches. By 1960 two separate paths emerged from the process approach in opposite directions. These new paths became known as the quantitative and behavior approaches to management.

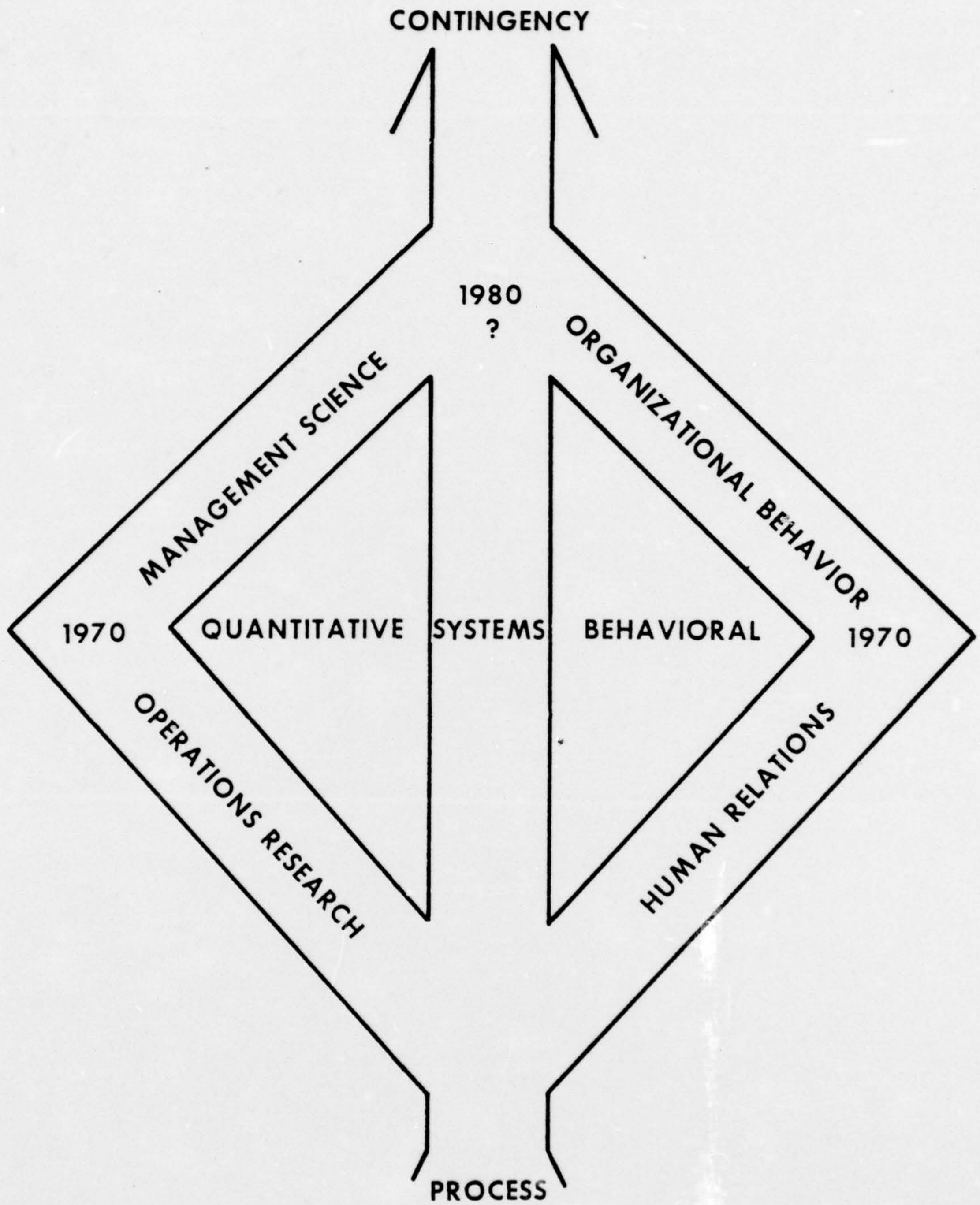


FIGURE 10

EVOLUTION OF THE VARIOUS MANAGEMENT THEORIES

B. APPROACHES TO MANAGEMENT

1. The Quantitative Approach

The quantitative approach, emerging in early 1960, has its roots in the scientific management movement that actually predates the process approach. This approach was characterized by the techniques of operations research which used various mathematical models to solve decision problems. However it soon became apparent that this approach fell short of providing a theoretical base for management as a whole, although operations research techniques did provide effective tools for management decision making.

Starting in about 1970, the quantitative approach turned away from emphasis on narrow operation research techniques toward a broader perspective of management science. In addition to the quantitative decision making techniques and model building as in OR the function of computerized information systems and operations management were incorporated. This then marked the return toward a more broadly based theory of management.

2. The Behavioral Approach

The other separation from the process approach, the behavior approach, was charactirized by human relations. Assumptions were made about human beings and solutions to behavioral problems were offered. Improving morale was a major concern, which did no harm, but unfortunately not all desired results were obtained.

Again around 1970 the behavioral approach had a parallel development with the quantitative approach. A more broadly based organizational behavioral approach was followed. More direct attention is devoted to organization theory and organizational development. This approach is now the result of interaction between the human being and the formal organization.

3. The Systems Approach

While the quantitative and behavioral approaches were going their separate ways the systems approach appeared. Since 1960 this approach took up where the process approach left off in unifying management theory.

The theoretical systems approach can be traced back to the natural and physical sciences of the early 1950's. The application to management has been much more recent. The systems approach stresses the interrelatedness and interdependency of the parts to the whole.

As has been noted, both the management sciences and organizational behavioral approaches are heading back toward the main path of systems. In management science, the new emphasis on computer applications and operations management techniques are systems based. On the other side the formal organization is viewed as a system consisting of structures, processes, and technology and is composed of the human system which contains a biological-physiological structure, psychological processes, and a personality.

Only time will tell if the systems approach will unitify the quantitative and behavioral approaches to management.

If the three approaches do actually merge in the future than something different from the sum of their parts may emerge. The future theory is now being called the contingency theory.

4. The Contingency Theory

The contingency theory, sometimes referred to as situational theory is starting to emerge from the many management theories. This theory has been advanced largely by practicing managers. The complex, changing environment around an organization has created the situation of "it all depends" type of management philosophy.

The systems approach may however in time evolve to meet these situational theories. An open, as opposed to closed, systems view is better able to cope with increased complexities and environmental influences facing managers today. Systems concepts such as entropy and equifinability are quite applicable to the present managerial situations.

Nevertheless a mid-range concept that falls between "simplistic, specific principles" and "complex, vague notions" is being called for by several notable authors in the area. This contingency approach "recognizes the complexity involved in managing modern organizations but uses patterns of relationships and/or configurations of subsystems in order to facilitate improved practices" [Kast, 1972]. This author, however, feels that flexibility in the systems approach can provide the desired results.

APPENDIX C

SYSTEM MODELS

Systems may be represented by various types of models. The model, as used in this thesis, is an abstract representation of real phenomena. The objective of the model is not to portray or identify all aspects of phenomena, but rather to point out the significant elements and the salient interrelations. The following types of models are listed in order of their degree of abstraction.

1. Verbal Models

Verbal models rely on words to describe the elements and the interrelations of a particular system. Difficulties are encountered however in the ambiguities and semantic problems often encountered in verbal communication.

2. Schematic Models

Schematic models are basically a picture of a system and are typically drawings or charts that present systems elements or their attributes together with a single relation. Static schematic models depict a set of elements and their relations at a given point in time; such as maps, bar charts, Gantt Charts, the breakeven chart, and the organizational chart. Flow schematic models are schematic models that protray flow or movement of some description among the system elements, such as the Program Evaluation and Review Technique (PERT), and the decision tree. Dynamic system models are schematic

models that depict a transformation process. Inputs are processed into outputs under the direction of a controller. It is this model which will be used to analyze the systems approach to test and evaluation management.

3. Iconic Models

Iconic models are static three-dimensional representations of physical objects such as models used in wind tunnel testing.

4. Analog Models

Analog models seek to describe the operational characteristics of other systems through the process of analogy. These models are based on the premise that the behavior of full-scale systems may be studied by examining the behavior of other systems with similiar characteristics.

5. Mathematical Models

Mathematical models are symbolic models which represent the highest level of abstraction in systems model construction. These models are either deterministic or stochastic in nature and may be either descriptive or optimizing in purpose.

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